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EVALUATION OF THE BOATMAN, INC. ARMET F.R.S. 1000 HELMET.(U)
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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
Panama City, Florida 32407

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 10-79

EVALUATION OF THE BOATMAN, INC. ARMET F.R.S. 1000 HELMET

JAMES R. MIDDLETON

NOVEMBER 1979

Approved for public release; distribution unlimited

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The Boatman, Inc. Armet F.R.S. 1000 helmet was tested by NEDU in accordance with MIL-R-24169A. Results of unmanned testing which evaluated breathing resistance, pressure drop out of the first stage regulator, and breathing work showed that the helmet meets or exceeds all mil spec requirements. The helmet is not recommended for inclusion on the list of equipment Authorized for Navy Use because the U.S.N. currently has no requirement for this type of equipment in addition to its own USN MK I Mod 0 Mask.

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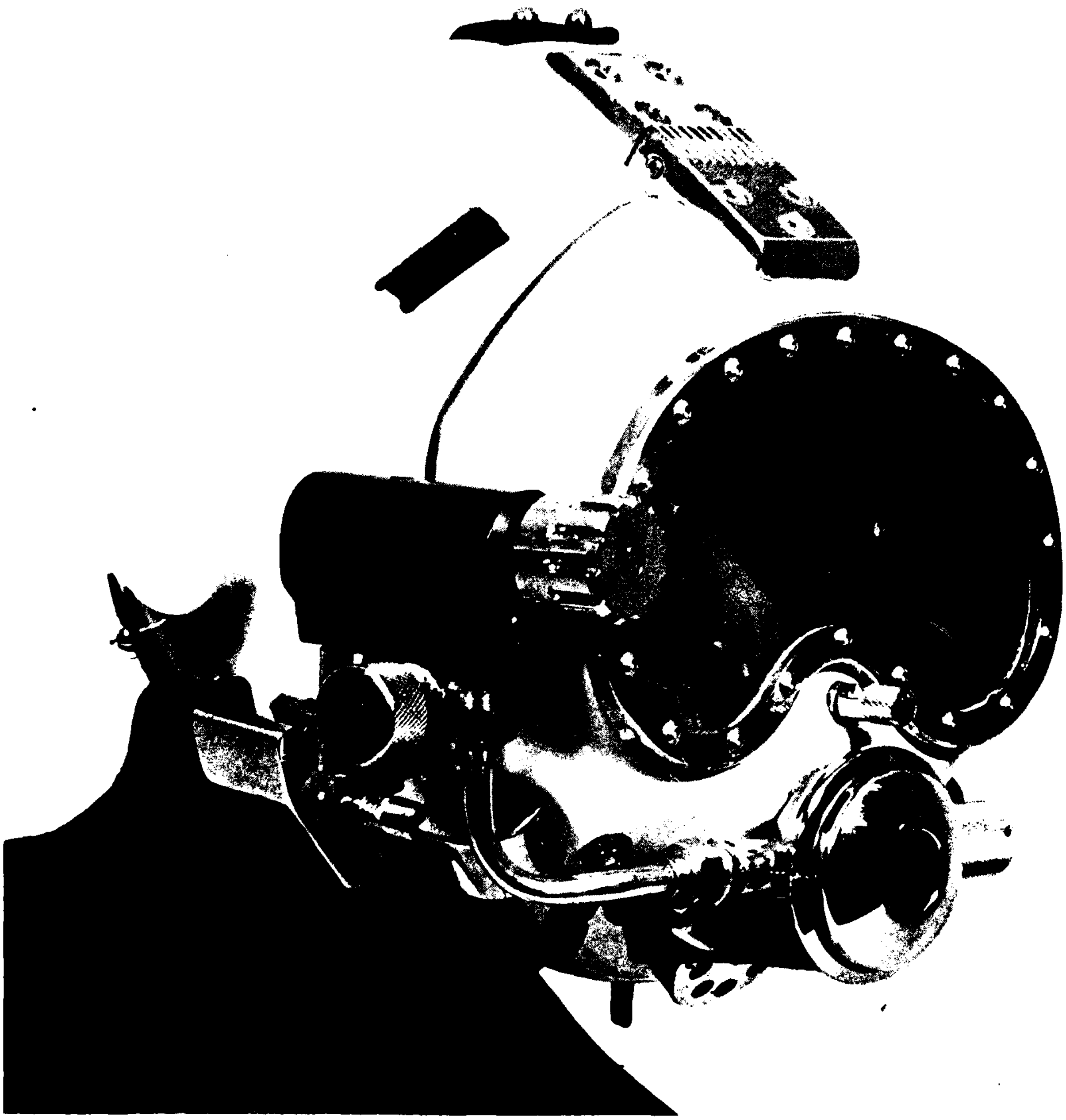
LIST OF ILLUSTRATIONS

Glossary

Abbreviation	Definition
BPM	breaths per minute
cm H_2O	centimeters of water pressure (differential)
FSW	feet sea water
HeO_2	helium-oxygen breathing gas
h.p.	high pressure
I.D.	inside diameter
kg.m/l	breathing work in kilogram meters per liter ventilation
LPM	liters per minute (flow rate)
mil spec	military specification MIL-R-24169A
NEDU	Navy Experimental Diving Unit
O/B	over bottom pressure
ΔP	pressure differential
psid	pounds per square inch differential
psig	pounds per square inch gauge
RMV	respiratory minute volume in liters per minute
USN	United States Navy

Abstract

The Boatman, Inc. Armet F.R.S. 1000 helmet was tested by NEDU in accordance with MIL-R-24169A. Results of unmanned testing which evaluated breathing resistance, pressure drop out of the first stage regulator, and breathing work showed that the helmet meets or exceeds all mil spec requirements. The helmet is not recommended for inclusion on the list of equipment Authorized for Navy Use because the U.S.N. currently has no requirement for this type of equipment in addition to its own USN MK I Mod 0 Mask.



Boatman, Inc. Armet F.R.S. 1000 Helmet

I. INTRODUCTION

In June 1979, NEDU tested the Boatman Armet FRS-1000, an umbilical supplied light weight helmet produced by Boatman, Inc., 4144 Erie Street, Houston, Texas, 77087.

The helmet was tested in accordance with MIL-R-24169A (reference 1) and other applicable standards. Various RMV's were used during the test to simulate light through extreme diver work rates. Pressure drop out of the first stage regulator was monitored to give an indication of total system performance. Breathing work required to operate the helmet was also measured.

The test results show that the Armet FRS-1000 helmet meets or exceeds all mil spec requirements.

II. TEST PROCEDURE

A. Test Plan

NEDU test equipment was set up as shown in Figure 1 and all testing of the helmet was done in accordance with applicable mil specs. The actual test plan is given in Appendix A. A breathing machine simulated diver inhalation and exhalation at various depths. The instrumentation and test equipment shown in Figure 1 is listed in Appendix B. Parameters controlled, measured, computed and plotted are listed below.

B. Controlled Parameters

The following parameters were controlled during this test:

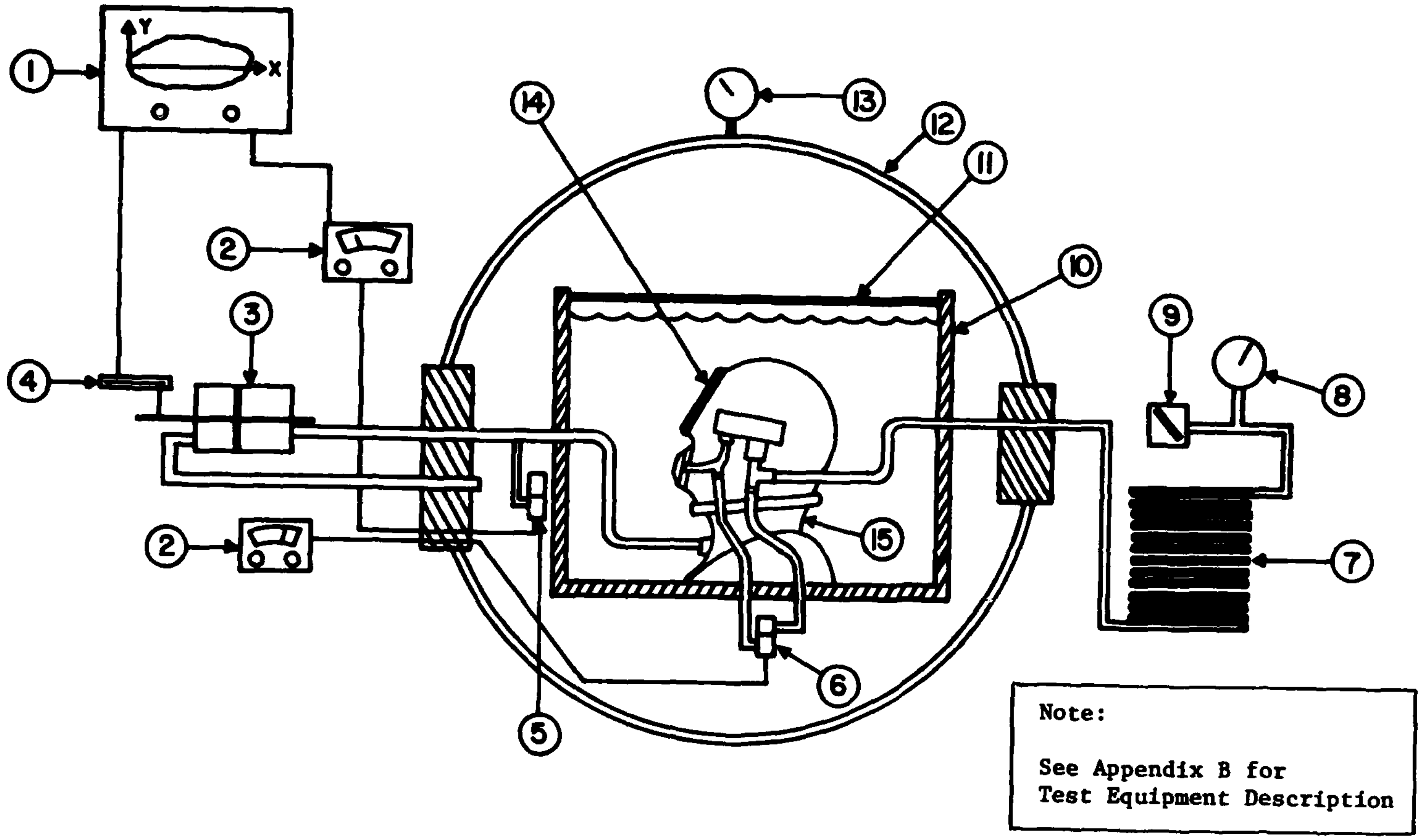
(1) Breathing Rate / Tidal Volume / RMV / Simulated Work Rate

	Breathing Rate	Tidal Volume	RMV	Simulated Work Rate
(a)	15 BPM	1.5 liters	22.5 LPM	Light
(b)	20 BPM	2.0 liters	40.0 LPM	Moderate
(c)	25 BPM	2.5 liters	62.5 LPM	Moderately/Heavy
(d)	30 BPM	2.5 liters	75.0 LPM	Heavy
(e)	30 BPM	3.0 liters	90.0 LPM	Extreme

(2) Exhalation/Inhalation time ratio: 1.00/1.00

(3) Breathing waveform: sinusoid

(4) Umbilical supply pressure: 400 psig at all depths, 150 psig O/B at 0, 99, 198 FSW



1. X-Y Plotter
2. Transducer Readout
3. Breathing Machine
4. Piston Position Transducer
5. Pressure Transducer (1.00 psid)
6. Pressure Transducer (20.0 psid)
7. 400' 3/8" I.D. Umbilical
8. Air Supply Gauge
9. Dome Loader
10. Wet Test Box
11. Bubble Dampening Mat
12. Chamber Complex
13. Chamber Depth Gauge
14. Armet FRS 1000 Helmet
15. Mannikin

Figure 1. Test Setup

(5) Supply gas: air

(6) Supply gas mode: Umbilical only

(7) Depth stops; 0 to 198 FSW in 33 FSW increments; and 300 FSW following 198 FSW.

(8) "Dial-A-Breath" position: The second stage adjustment knob was set for minimum breathing resistance at each O/B pressure tested (i.e., the knob was backed out until a free flow condition occurred and then turned back in just enough to stop the free flow).

C. Measured Parameters

The following parameters were measured on the F.R.S. 1000 test:

(1) Inhalation Maximum ΔP

(2) Exhalation Maximum ΔP

(3) ΔP vs. tidal volume plots

(4) Dynamic pressure drop out of first stage regulator from static setting

D. Computed Parameters

Respiratory work is computed from ΔP vs. tidal volume plots.

E. Data Plotted

The following data are plotted in this report:

(1) Inhalation maximum ΔP vs. depth at each RMV tested

(2) Exhalation Maximum ΔP vs. depth at each RMV tested

(3) Respiratory work vs. depth at each RMV tested

(4) Dynamic pressure drop out of first stage regulator vs. depth at each RMV tested

III. RESULTS AND DISCUSSION

A. Description

The Boatman Armet F.R.S. 1000 Helmet is a light weight, open circuit diving helmet which is designed for surface supplied or saturation umbilical diving. The helmet has the capability of operating in either the demand or free flow mode. The demand mode incorporates a "Dial-A-Breath" valve which allows a diver to maintain low breathing resistance regardless of gas supply pressure. The "Dial-A-Breath" valve is also used to create a free flow mode through the demand regulator. The diver's exhaled gas is vented through the exhaust valve in the demand regulator or through a supplemental exhaust valve located beneath the demand regulator housing.

A gas supply umbilical connects to the sideblock assembly on the right side of the helmet. The sideblock houses a non-return valve in the umbilical supply port and also incorporates a separate gas supply valve and connector for an emergency gas supply. The emergency supply normally consists of a standard scuba tank and first stage regulator assembly which is worn on the diver's back. In addition, the sideblock houses a defogging valve which may be used to supplement normal demand/free flow operation or to keep the face plate clear by directing a continuous flow of gas across the lens.

The breathing system has incorporated an enlarged first stage regulator into the sideblock assembly. This allows higher umbilical pressure to compensate for the deeper depths and long umbilicals, and stabilizes the pressure going to the second stage. This feature enables the topside dive supervisor to supply the diver with whatever h.p. gas pressure is available (i.e. generally 300 to 500 psig) without concerning himself with maintaining a specific over-bottom supply pressure. This function is performed at the sideblock by the integral first stage regulator. When low umbilical pressures are used, the regulator ports are large enough so that the flow is not constricted. Breathing adjustment is made with the second stage "Dial-A-Breath" since the sideblock is then functioning in a conventional manner.

The helmet incorporates a flexible dry hood and a face ring seal, eliminating the use of a neck ring. The helmet can be worn either with the hood, or without, like a mask. It can be mated to any type of diving suit, wet or dry.

B. Breathing Resistance Tests

Breathing resistance was measured at five RMV's to simulate light through extreme diver work rates. Light work was simulated at 22.5 RMV, moderate work at 40 RMV, moderately heavy work at 62.5 RMV, heavy work at 75.0 RMV and extreme work at 90.0 RMV. The mil spec (reference 1) calls for 40 RMV only. The other RMV's were measured, however, to indicate the full range of helmet performance.

The breathing resistances plotted in the figures are the maximum values measured, excluding cracking pressure, during one complete inhalation-exhalation cycle at a given depth and RMV. On plots where data is incomplete, the test

was terminated due to excessive breathing resistance. Sample recorded pressure-volume loop and breathing cycle data are shown in Figures 2 and 3.

The following table lists equivalent depth densities for air versus HeO_2 down to 200 FSW on air. This provides a means of comparing helmet performance on HeO_2 mixes at depths greater than 200 FSW.

Air Depth (FSW)	Equivalent HeO_2 Depth (FSW)
50	300
100	730
150	1100
200	1500

(1) Inhalation Characteristics

The inhalation resistances plotted are the maximum pressures recorded, except for cracking pressures, at all RMV. Maximum flow resistance always occurred at the point of peak flow rate during the inhalation and exhalation cycles. "Dial-A-Breath" position was set as previously described for minimum breathing resistance at a specific O/B pressure and left for the duration of the test.

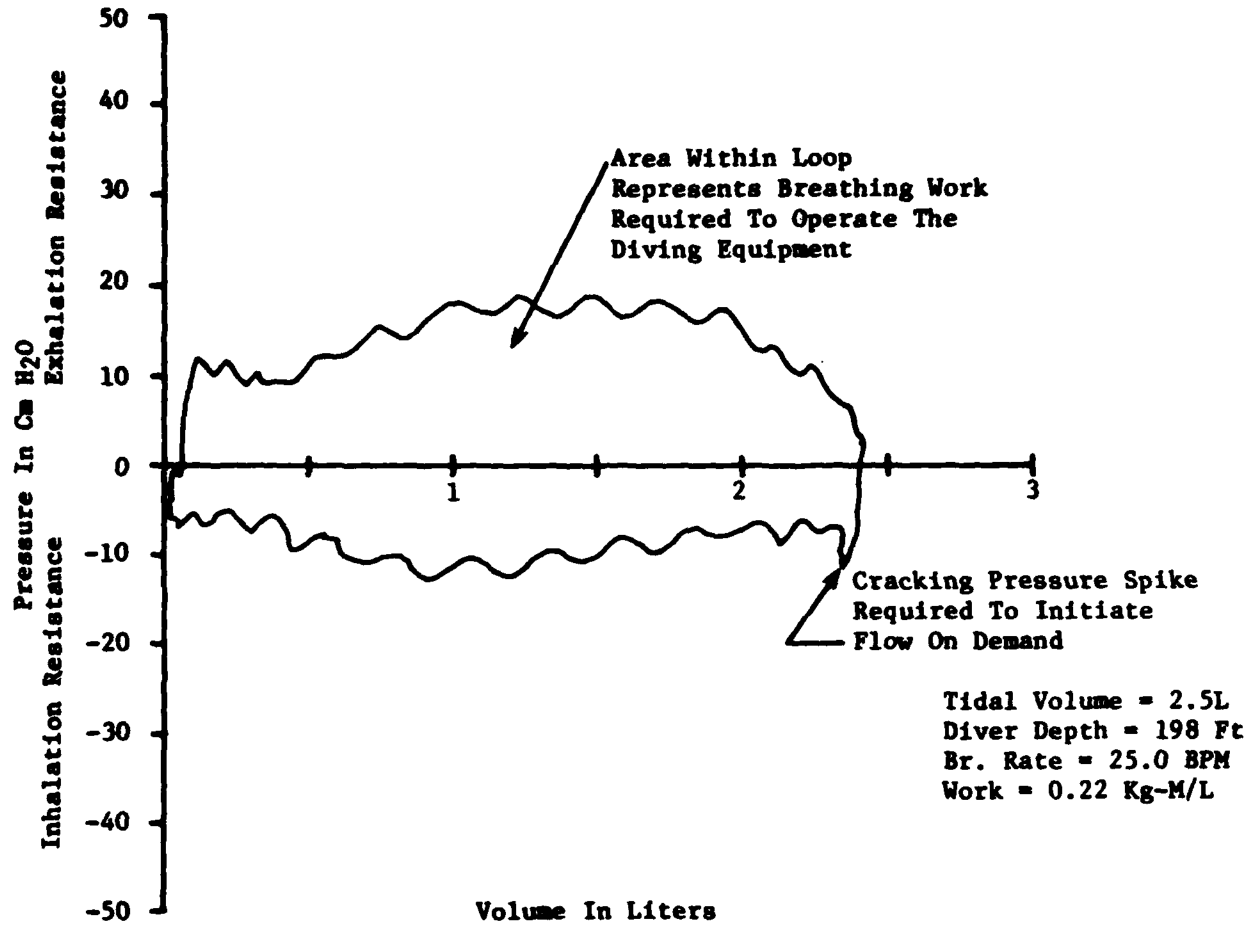
The cracking pressure of the F.R.S. 1000 was low and generally was accompanied by smooth flow.

This initial pressure spike required to initiate flow on inhalation represents very little breathing work and is ignored when it exceeds peak flow differential pressures. The reason for high pressure differentials to initiate flow in a demand regulator is usually an incorrectly adjusted diaphragm linkage assembly. This represents no threat to the diver's life support system or its overall performance. Typical pressure-volume data is represented in Figures 2 and 3.

Inhalation resistance at 400 psig supply pressure remains almost constant at 22.5 (Figure 4) and 40 RMV (Figure 5) regardless of depth, never exceeding 14cm H_2O. These values are very low and represent easy breathing even at 300 FSW.

At 62.5 RMV (Figure 6) inhalation effort increases to a maximum of 20cm H_2O at 198 FSW. This is still within the mil spec limit for a moderately working diver and is considered satisfactory at this moderately heavy work rate.

Seventy-five RMV (Figure 7) inhalation effort did not increase substantially over 62.5 RMV until 198 FSW. At this point resistance jumped to 37cm H_2O. However, 75 RMV represents heavy diver work and the helmet's performance under these conditions is excellent.



Breathing Pressure Versus Tidal Volume Loop

Figure 2. Sample Pressure-Volume Loop

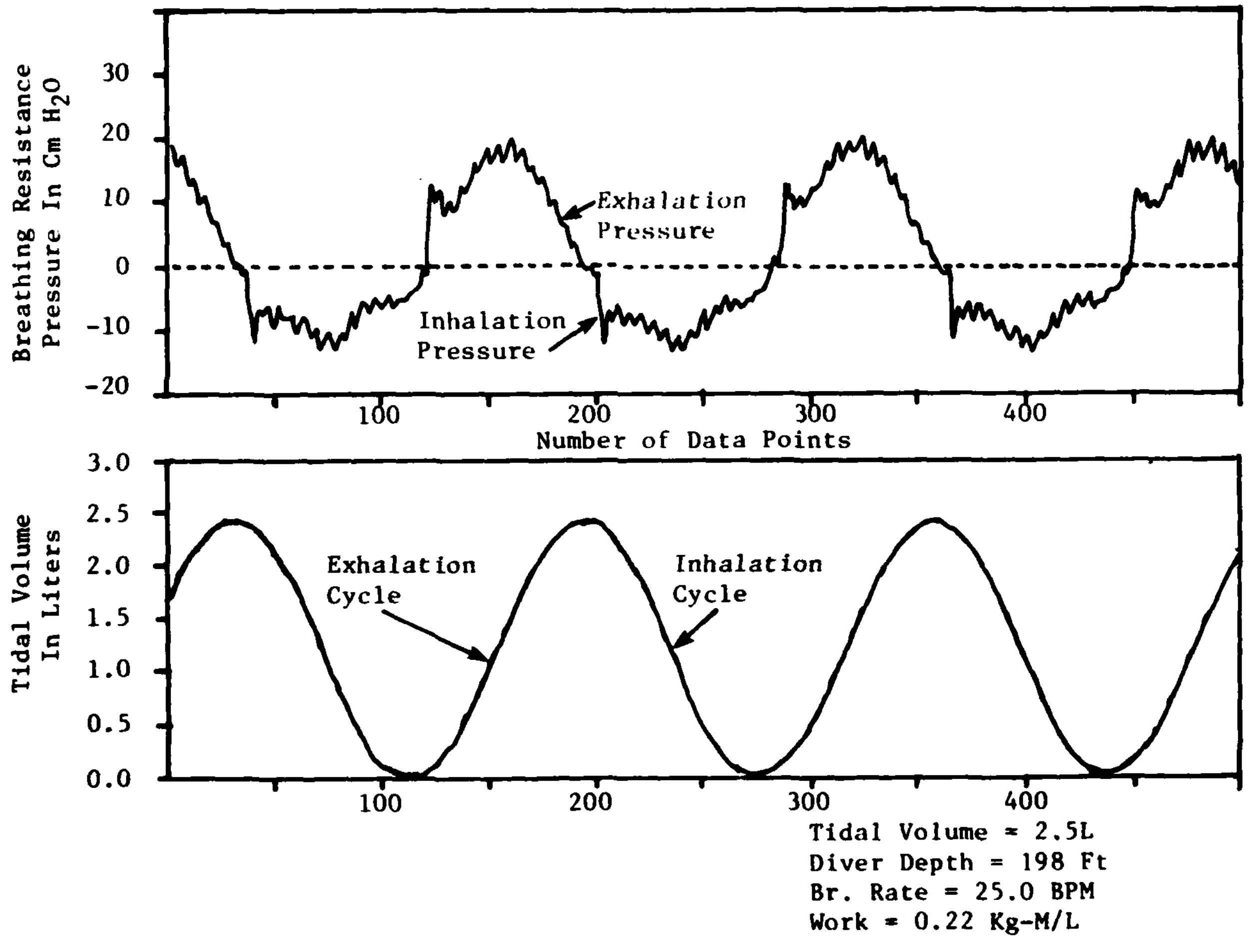


Figure 3. Sample Breathing Cycle Data

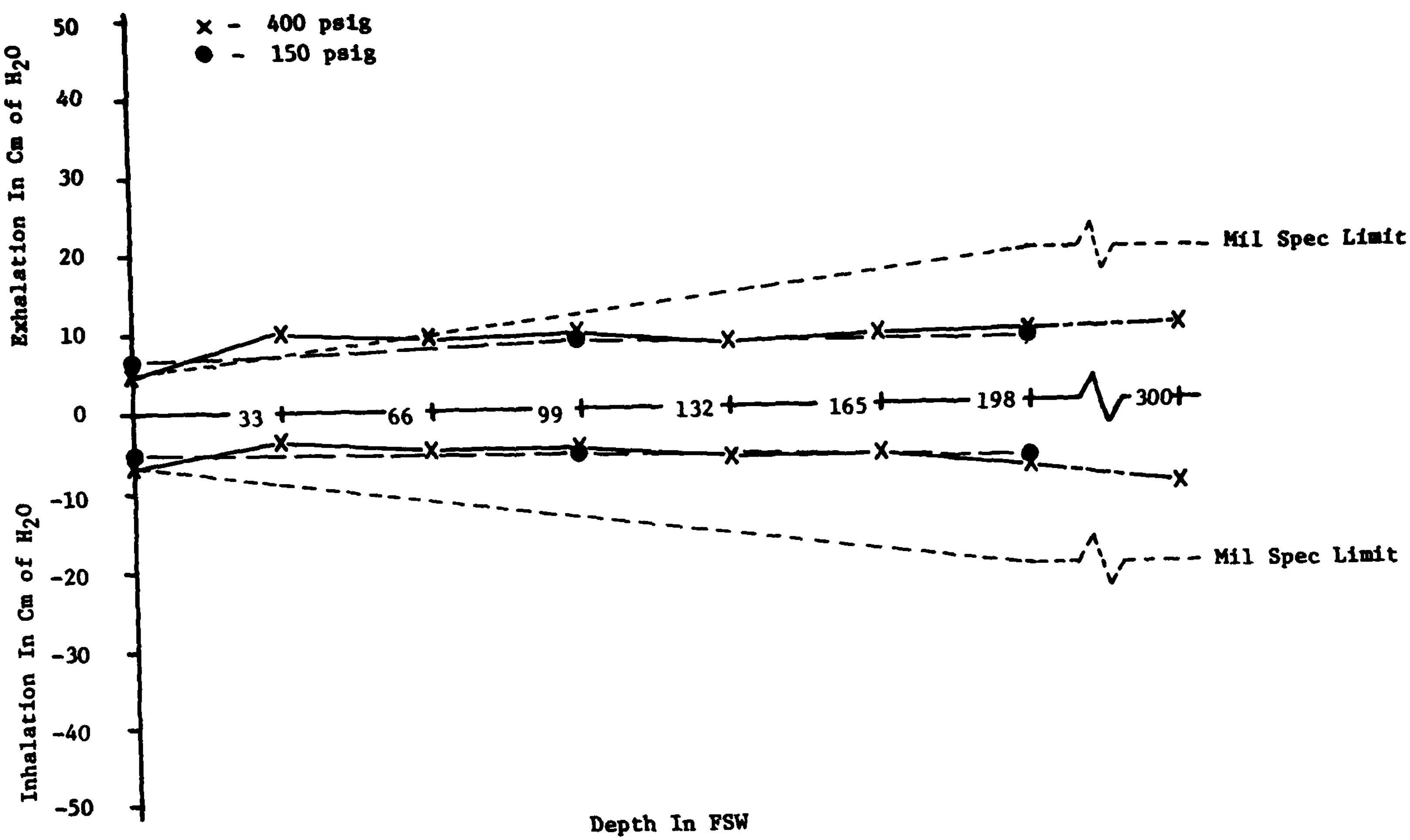


Figure 4. Breathing resistance vs. depth
400 psig and 150 psig O/B supply pressure
at 22.5 RMV

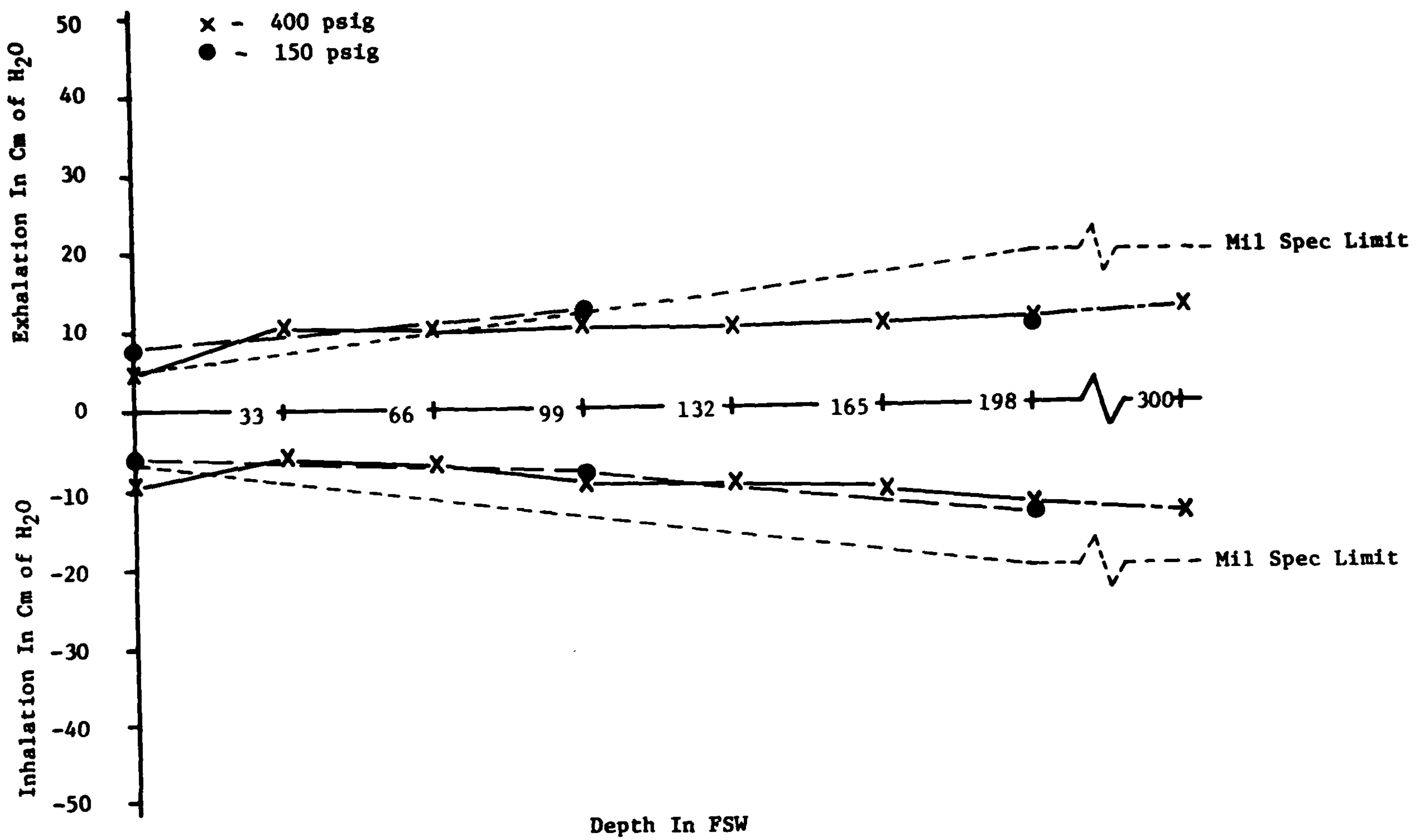


Figure 5. Breathing resistance vs. depth
400 psig and 150 psig O/B supply pressure
at 40 RMV

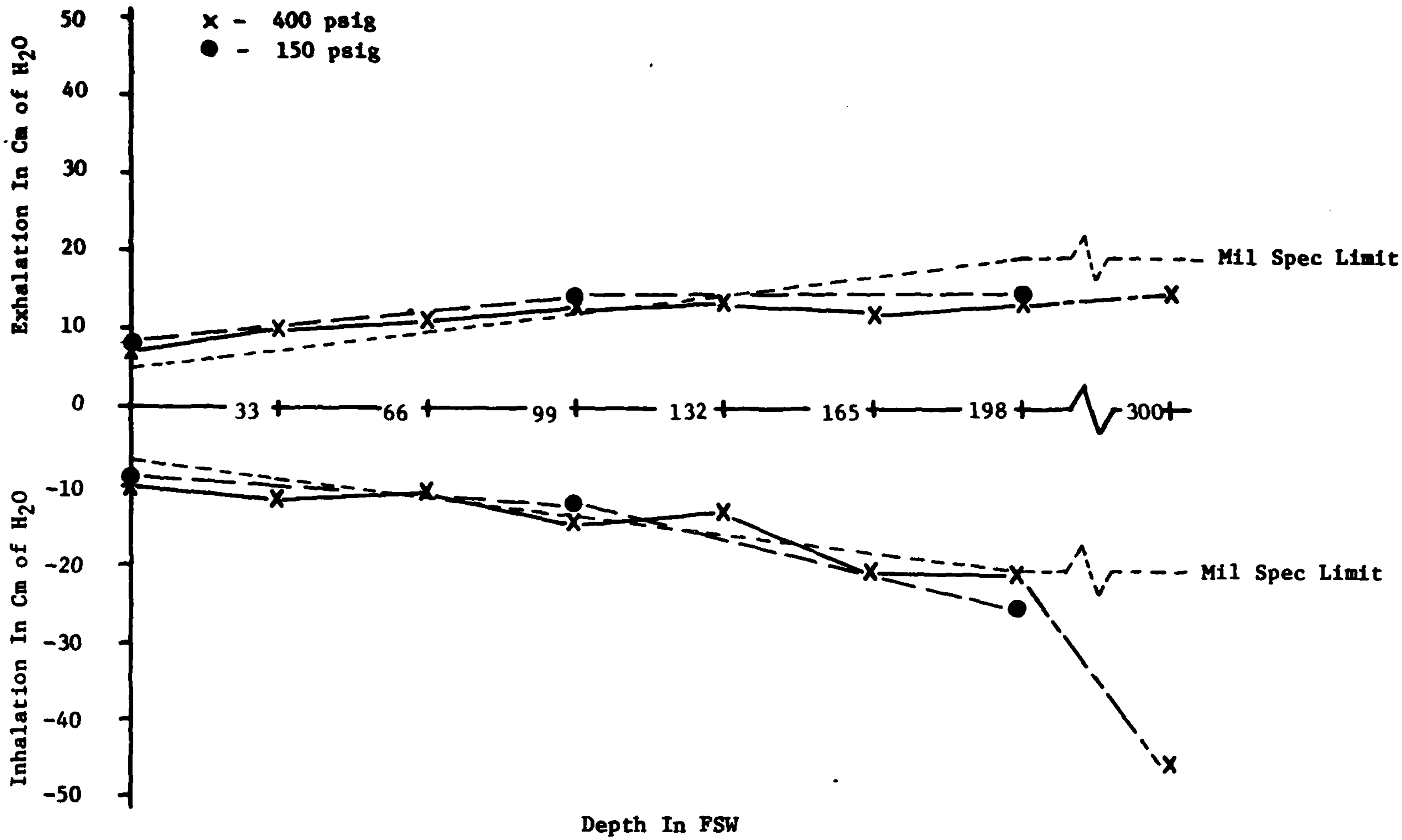


Figure 6. Breathing resistance vs. depth
400 psig and 150 psig O/B supply pressure
at 62.5 RMV

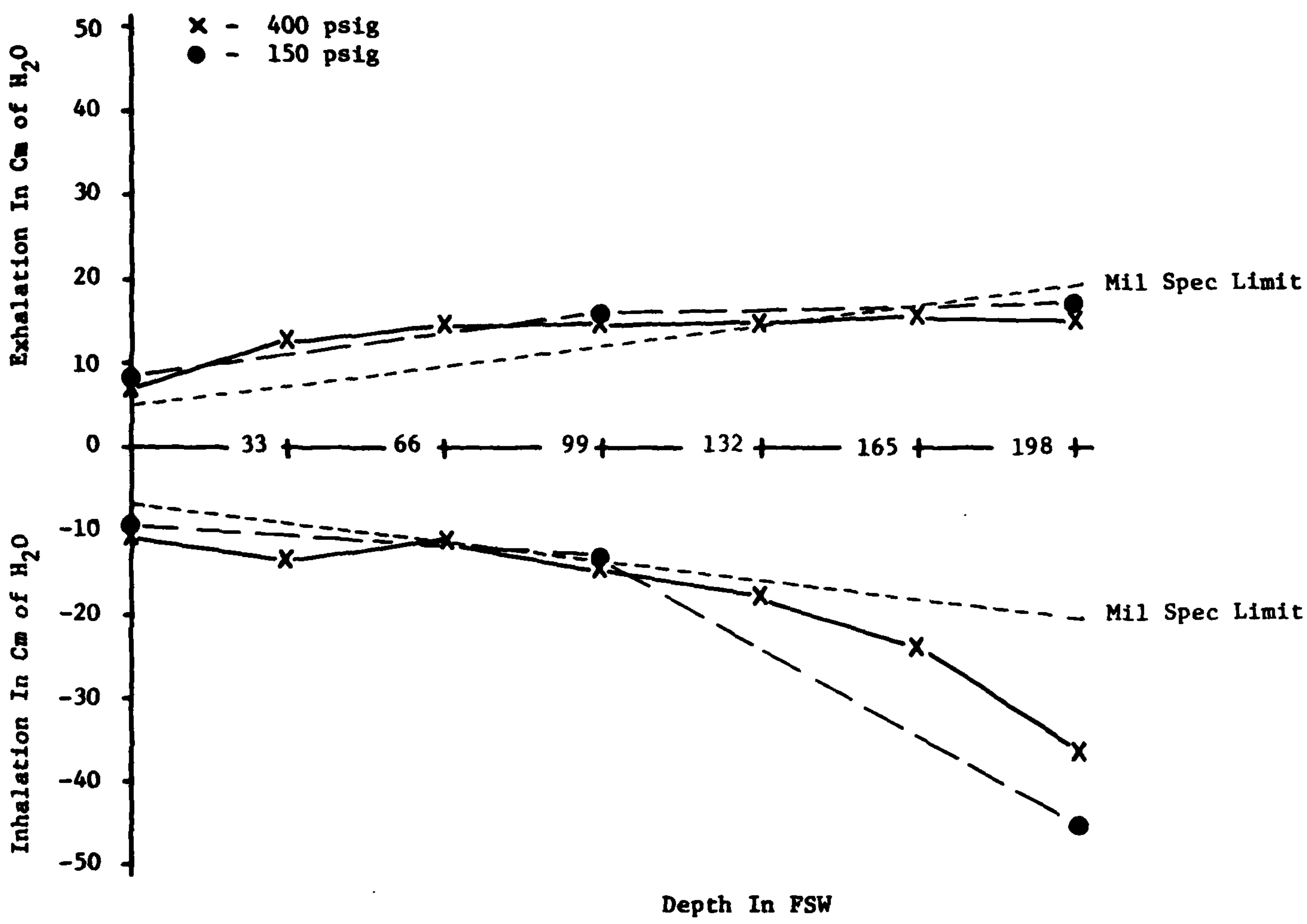


Figure 7. Breathing resistance vs. depth
400 psig and 150 psig O/B supply pressure
at 75 RMV

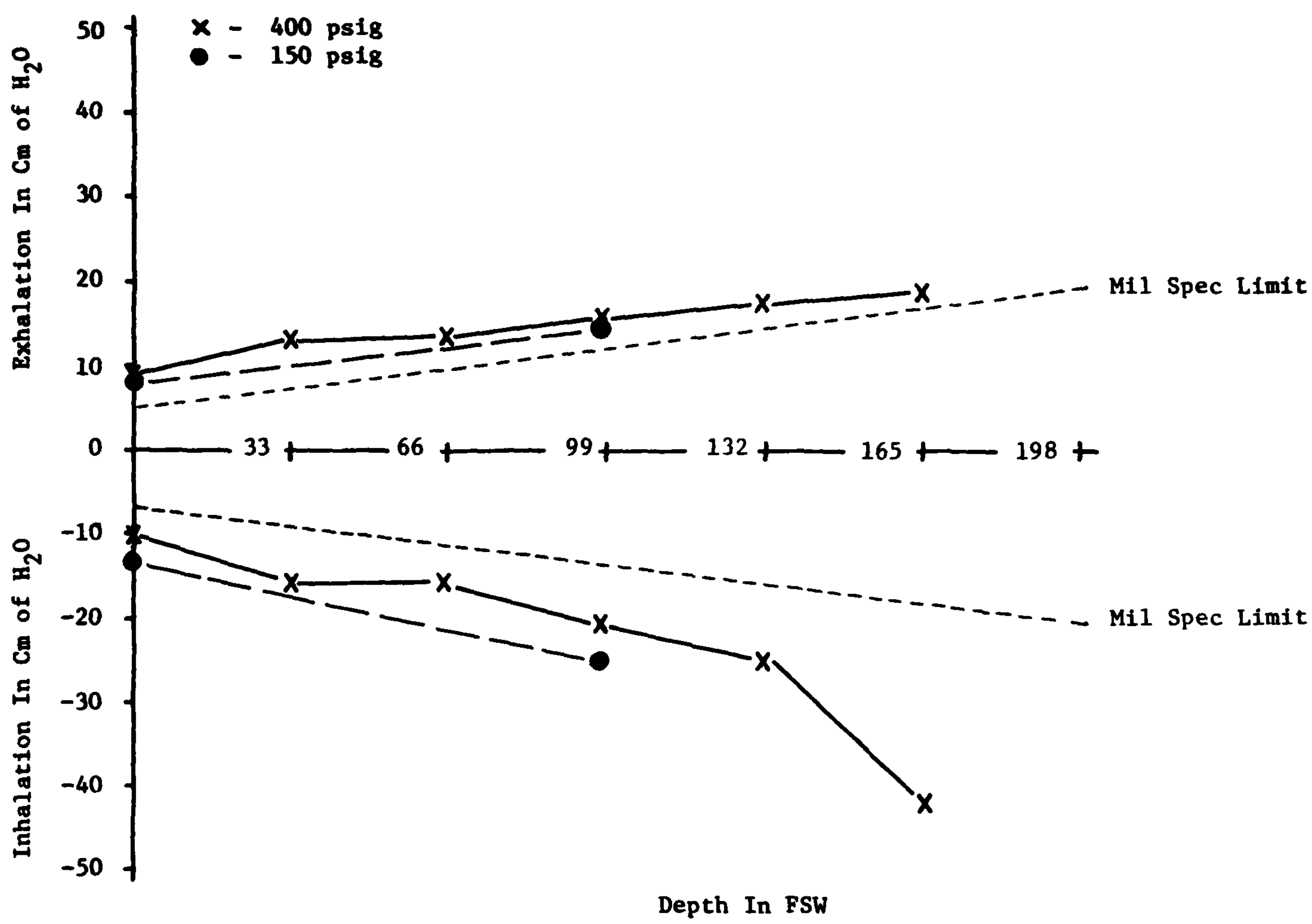


Figure 8. Breathing resistance vs. depth
400 psig and 150 psig O/B supply pressure
at 90 RMV

The extreme work rate of 90 RMV (Figure 8) produced acceptable breathing resistance at depths down to 132 FSW. It should be noted that this work rate can be sustained by a diver for only very short periods of time and is an extreme performance level for any type of diving equipment.

At 99 FSW and 198 FSW gas supply pressure to the first stage side block was reduced from 400 psig to 150 psig O/B to evaluate work performance at low supply pressures. Here the first stage ceases to function and the sideblock acts only as a conventional manifold. No significant degradation in helmet performance was observed at RMV's up to 62.5 RMV. Performance was significantly reduced at 198 FSW and 75 RMV with breathing resistance exceeding 40cm H_2O.

(2) Exhalation Characteristics

At 22.5 (Figure 4) and 40 RMV (Figure 5) exhalation resistance was extremely low, never exceeding 10cm H_2O. Resistance at 62.5 (Figure 6) and 75 RMV (Figure 7) was almost identical and still well within the mil spec limit for 40 RMV. Ninety RMV (Figure 8) exhalation pressures increased over the 75 RMV values but not significantly. In general, the exhalation breathing characteristics were impressive even at high diver work rates.

C. Work of Breathing

Breathing work (Figure 9) required for the Armet F.R.S. 1000 was very low at 22.5 and 40 RMV, reaching a maximum of only 0.19 kg.m/l at 300 FSW. At 62.5 and 75 RMV breathing work did not significantly exceed the proposed limit until a depth of 300 FSW was reached. Work rates increased rapidly beyond 66 FSW at the extreme work rate of 90 RMV. At 165 FSW and 90 RMV breathing work reached levels considered safe only in emergency conditions.

Breathing work was also measured at 99 and 198 FSW with only 150 psig O/B supply pressure. The pattern was similar to breathing resistances encountered at the reduced supply pressures with no significant increase occuring until 198 FSW at 75 RMV.

It is important to note that these values are using air as the breathing gas and these values using HeO_2 correspond to much greater depths for the same work rates.

D. Sideblock/First Stage Performance

The design of the Boatman Armet F.R.S. 1000 sideblock is unique. An enlarged balanced piston regulator is built into the sideblock. This feature enables the topside dive supervisor to simply supply the diver with whatever h.p. supply pressure is available (i.e., generally 300 to 500 psig) without concerning himself with maintaining a specific over bottom supply pressure. The regulator in the sideblock performs this function by maintaining an outlet pressure to the second stage of 165 psig O/B. This feature has the potential

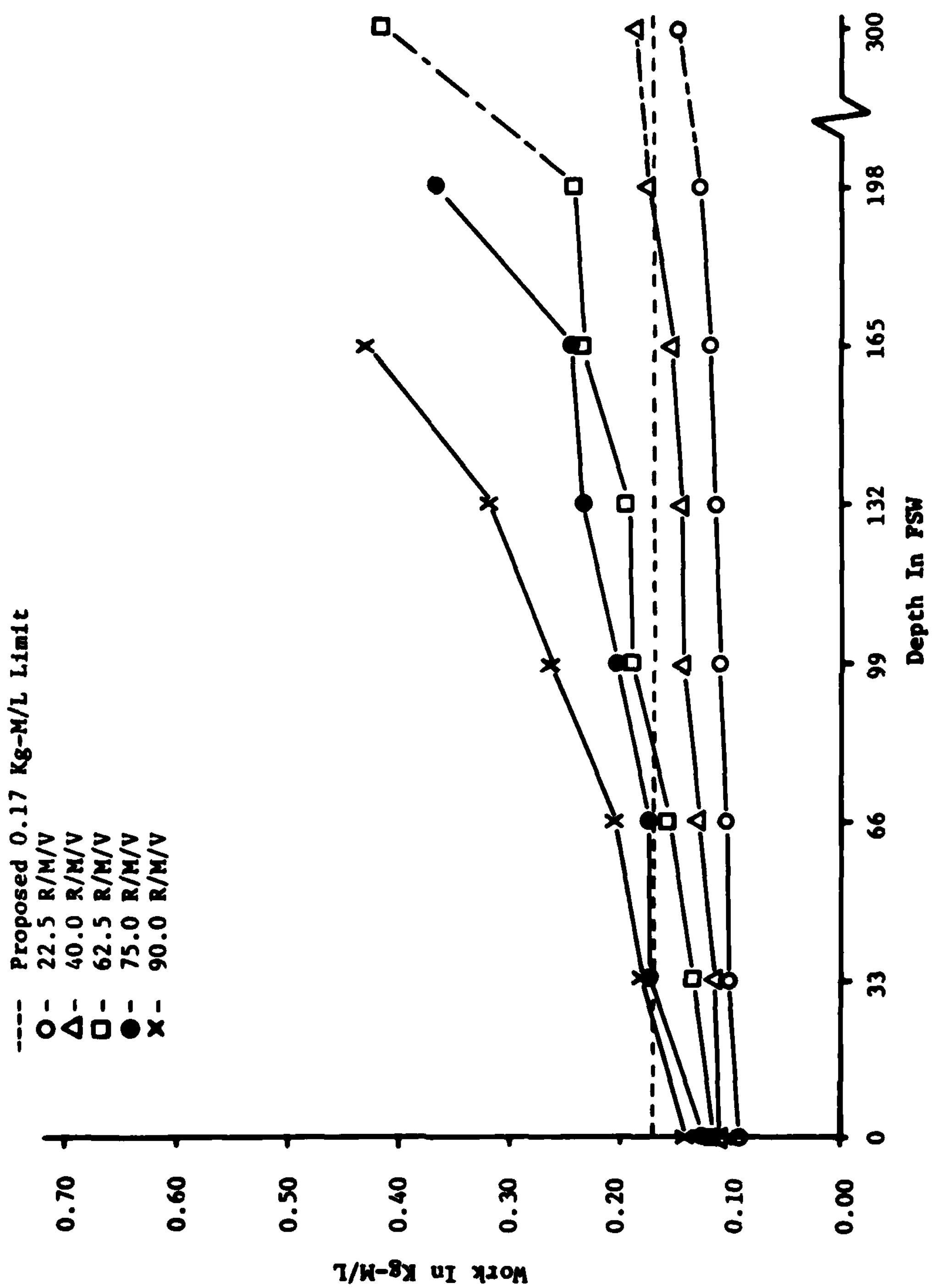


Figure 9. Breathing work vs depth
400 psig supply pressure

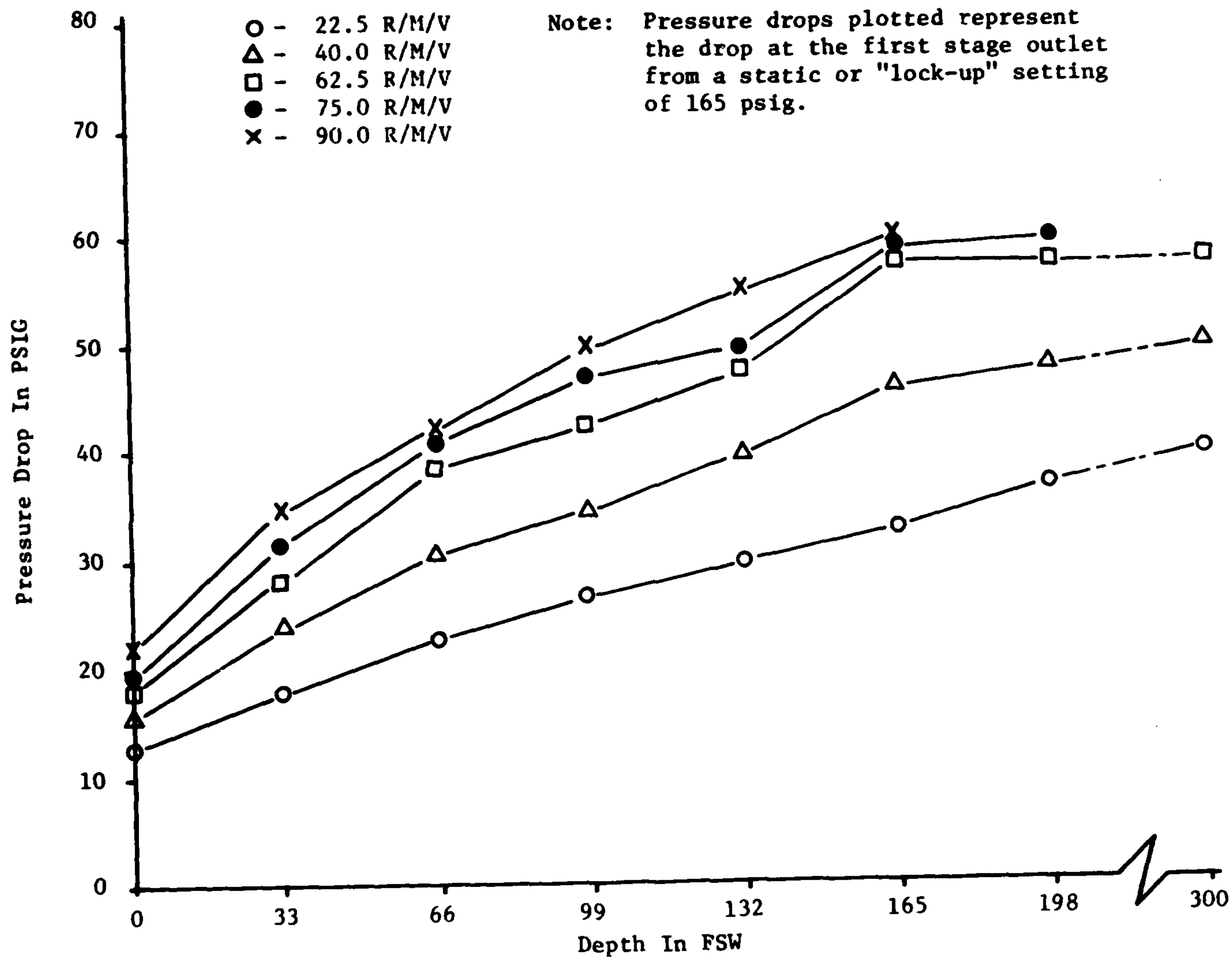


Figure 10. First stage pressure drop vs. depth
400 psig supply pressure

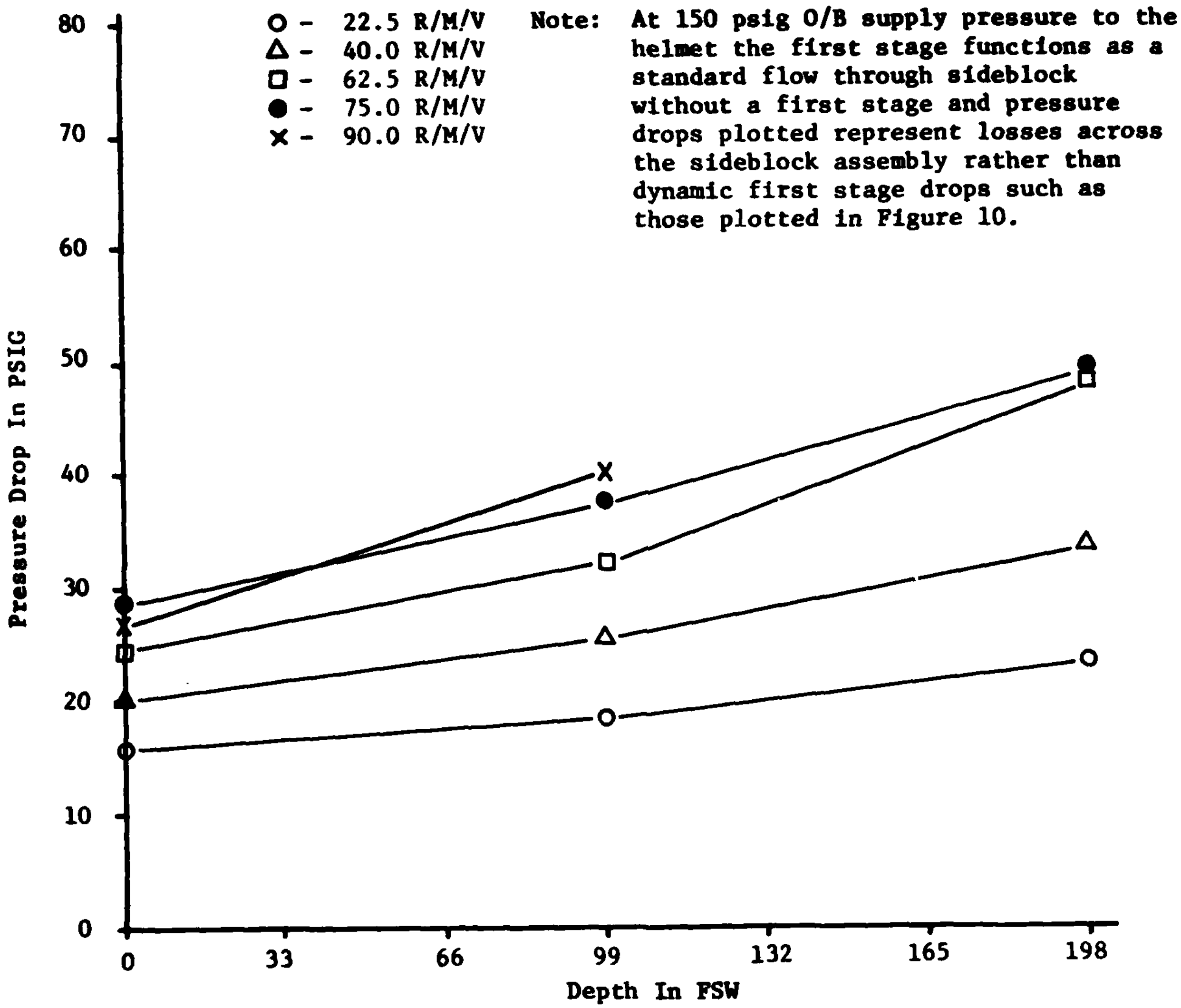


Figure 11. First stage pressure drop vs. depth
150 psig O/B supply pressure

of significantly reducing the complexity of diving operations while maintaining a high degree of diver safety and equipment reliability.

At supply pressures below 165 psig O/B the sideblock/first stage regulator functions as a standard flow-through manifold.

Intermediate pressure drop under flow conditions between the first and second stages was monitored to evaluate regulator performance at a given depth and RMV. Maximum intermediate pressure drop from the first stage static or "lock-up" setting was plotted. By correlating this information with breathing resistance plots, poor mask performance can be traced to the first stage, second stage or both stages.

The factory-set static pressure is 165 psig O/B. Figure 10 plots the pressure drops from the static setting versus depth at various RMV. A general guide to evaluating first stage performance is that when the supply pressure drops off 50 psig from the static setting the first stage has reached the limit of its design. For example, at 90 RMV breathing resistance increases drastically between 132 and 165 FSW. This corresponds to a pressure drop at the first stage outlet of 52 and 60 psig respectively. In other words, at this point the first stage can no longer supply an adequate flow of gas to the second stage to maintain easy breathing characteristics.

Figure 11 shows the drop across the sideblock when it is functioning as a conventional flow-through manifold.

IV. CONCLUSIONS AND RECOMMENDATIONS

The Boatman Armet F.R.S. 1000 is considered to be a safe and effective diver life support system. The F.R.S. 1000 is not recommended for placement on the list of equipment authorized for Navy use because the U.S.N. MK 1 Mod 0 Mask currently meets all fleet needs for this type of equipment.

Breathing resistance was low even at heavy diver work rates at all depths down to 165 FSW. Results indicated low cracking pressures on the demand regulator with smooth even flow through the breathing cycle.

Breathing work required to operate the mask was generally low and would not inhibit a diver's ability to perform useful work except in extreme cases.

Pressure and flow characteristics of the sideblock/first stage regulator were exceptional. This concept presents a reasonable alternative to conventional topside over bottom pressure control by the dive supervisor.

In general, the Boatman Armet F.R.S. 1000 is well built and easy to use and maintain. It should provide the working diver with a functional and dependable piece of life support equipment.

V. REFERENCES

1. Department of the Navy Military Specification MIL-R-24169A, Regulator, Air, Demand, Single Hose, Nonmagnetic, Divers, 22 March 1967.

2. Navy Experimental Diving Unit Report 23-73, U.S.N. Procedures for Testing the Breathing Characteristics of Open-Circuit Scuba Regulators, by S. D. Reimers, p. 5, 11 December 1973.

3. Navy Experimental Diving Unit Report 19-73, Proposed Standards for the Evaluation of the Breathing Resistance of Underwater Breathing Apparatus, by S. D. Reimers, p. 36, 30 January 1974.

APPENDIX A

TEST PLAN

1. a. Insure that regulator is set to factory specifications and is working properly.

   b. Chamber on surface.

   c. Calibrate transducer and then zero transducer after water is added to arc.

   d. Open air supply valve to test regulator and set supply pressure at 400 psig.

   e. Adjust breathing machine to 1.5 liters tidal volume and 15 BPM and take data.

   f. Adjust breathing machine to 2.0 liters tidal volume and 20 BPM and take data.

   g. Adjust breathing machine to 2.5 liters tidal volume and 25 BPM and take data.

   h. Adjust breathing machine to 2.5 liters tidal volume and 30 BPM and take data.

   i. Adjust breathing machine to 3.0 liters tidal volume and 30 BPM and take data.

   j. Adjust air supply pressure to 150 psig O/B and repeat steps 1e-1i.

2. a. Pressurize chamber to 66 FSW in 33 FSW increments and repeat steps 1d-1i at each stop.

   b. Pressurize chamber to 99 FSW and repeat steps 1d-1j.

   c. Pressurize chamber to 165 FSW in 33 FSW increments and repeat steps 1d-1i at each stop.

   d. Pressurize chamber to 198 FSW and repeat steps 1d-1j.

   e. Pressurize chamber to 300 FSW and repeat steps 1d-1i.

APPENDIX B

TEST EQUIPMENT

(Note: Equipment corresponds to that in Figure 1.)

1. X-Y plotter
2. Validyne CD-23 transducer readout (2 ea.)
3. Breathing machine
4. Breathing machine piston position transducer
5. Validyne pressure transducer w/1.00 psid diaphragm
6. Validyne pressure transducer w/20.0 psid diaphragm
7. 400 ft. of 3/8" I.D. umbilical
8. External air supply pressure gauge
9. Dome loader
10. Wet test box
11. Bubble dampening mat
12. EDF chamber complex
13. Chamber depth gauge
14. Test helmet: Boatman Armet F.R.S. 1000